Communication[1]

iGEM 2022, University of Sheffield

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[1] from https://2022.igem.wiki/sheffield/communication

Over the year we have introduced aspects of synthetic biology to schools around the UK and shared our technical knowledge with fellow iGEMers!

At rEvolver we work tightly around our ethos and values which aim to make synthetic biology practices accessible and modular — providing a framework for future generations to follow.

We had the pleasure of delivering a range of outreach sessions this year, including highschool and primary school outreach sessions, computational biology sessions, and also talks introducing AlphaFold software. These programs and talks were tailored to iGEM students or young researchers who wouldn't haven't yet had the opportunity to learn about these areas of synthetic biology and apply them in a real-life research context.

We all agree that our STEM journey began with inspiring teachers, who brought difficult concepts to our fingertips and left us wanting to learn more. We wanted to continue this, and found ourselves in a unique position to educate and inspire younger generations of scientists with our work. Delivering these outreach programs surrounding iGEM and synthetic biology brought a sense of accomplishment, camaraderie and community to our lives which occur seldom in a laboratory setting.

Outreach into Schools

Although most STEM outreach programs focus on students beyond GCSE level, it is equally important to inform children at a young age about research. Science outreach is fundamental to closing the gap between science and society, however it often fails to reach those of younger generations, particularly at Primary school level. We targeted audiences of different ages, abilities and interests thus tailored creative materials to forge an open dialogue for deeper understanding and engagement.

Effective educational STEM outreach is greatly needed in our quickly advancing technical society; scientific literacy will be essential for adequate participation in the future of synthetic biology.

Secondary School Outreach

Despite being a rapidly growing area of biology, the A-Level syllabus has seemingly not caught up to the development of synthetic biology,

and as such a very limited amount of detail is given to students regarding modern biotechnological research and progress. We sought to aid this, by orchestrating an "Introduction to Synthetic Biology and Genetic Engineering" talk and interactive activity with students of Dronfield Henry Fanshawe School - the secondary school of one of our members: Isaac, who led the talks alongside Brooks and Connie.

In the week prior, Isaac and Connie worked on a detailed plan of the content that would be suitable to cover. Information on the level of detail the A-Level students had already covered was provided by the school.

They had covered:

- The structure of DNA, and the experimental evidence
- The concept of, and evidence for, semi-conservative replication
- A surface-level understanding of the central dogma of molecular biology, and some knowledge of RNA polymerase

They had not covered, but will cover eventually:

- Genetic architecture, promoters and transcription factors
- Genetic engineering, restriction enzymes and cloning procedures
- Biotechnology as a field.

Therefore, we planned to give students a broad introduction to the ethos of synthetic biology. We first emphasised the importance of the relationship between understanding and design in science, and highlighted that this has only reached maturity very recently for biology - after the discovery of the structure of DNA and learning how to manipulate it. Connie likened the rationale of synthetic biology to carpentry: carpenters go out and cut down trees, refine the materials into building blocks and then build various structures out of them that are useful to humans - analogous to synthetic biologies identifying useful genes, harvesting them via restriction digests/cloning and creating new structures.

We then briefly refreshed students about the central dogma of molecular biology, before introducing them to the concept of gene expression being dynamic and controllable, i.e. "genes aren't always turned on". We then asked the question: how is gene expression controlled? From here, we segued into promoters and their action of controlling the rate of transcription by binding transcription factors that up or downregulate transcription. We illustrated this by introducing the lac operon - and highlighted that the LacI repressor was acting as a "biosensor" - enabling cells to alter their genetic expression in response to the environment (i.e., lactose concentration).

Next, we introduced the students to the everyday tools of molecular biology as something we need in order to harvest our genetic parts of interest (or "cut down the trees") - restriction enzymes - and something we need to glue our parts together - ligase.

With these tools, we explained that new genes can be created by extracting genetic parts of interest using restriction enzymes, and reassembling them in novel combinations with ligase. We outlined this in the simplest of terms - i.e, a promoter of interest can be fused to a gene of interest to create a circuit whereby a product is expressed in response to a desired signal - but highlighted that the underlying principles to genetic assembly is the same for more complex circuits.

We attempted to get the students involved by asking them to create a simple gene fusion that would produce human insulin in response to the presence of glucose. Most students seemed to understand the basic process of assembling novel gene circuits, and were able to construct a glucose biosensor upstream of an insulin gene. Some students were even intuit the overall molecular cloning process with a small amount of guidance from us.

We then highlighted many applications of synthetic biology, ranging from simple metabolic engineering of microbial drug factories to more complicated efforts such as C4 photosynthesis engineering, lab grown meat and TNT biosensors. Again, we highlighted that although these applications involve a lot of thought and some more complicated considerations - the underlying principles of genetic engineering remain the same.

We introduced the students to the iGEM competition as an intrinsic part of synthetic biology. We explained that it consists of University level students attempting to solve a world or scientific problem using genetic engineering - and gave a few examples of winning projects including: production of violet scent chemicals, vineyard disease diagnostic tools and novel cancer therapies. We then referred back to the idea of restriction sites in molecular cloning, and explained that the existence of many restriction enzymes and their respective target sequences can complicate cloning procedures - and that one of iGEM's goals is to convert genetic parts into a "standard", such that flanking standardised restriction sites allow for simplified genetic assembly like "LEGO bricks".

Finally, we briefly discussed our plans to make a bioreactor that evolves a gene of interest for a desired purpose. We likened directed evolution to "selective breeding on the molecular level", and briefly explained that we were going to genetically engineer our bacteria to deliberately mutate our gene of interest. We did not expand on this too much since the details of RNA regulation, RNA polymerase action, dCas9 and more complex genetic circuitry are beyond the

scope of A-Level.

We finished by giving students the opportunity to ask any questions - to which we received a lot of engagement. Some of these questions were specific to the content - details on rationale in picking restriction enzymes, details as to how to perform these procedures in the lab. A lot of questions were centred around what it is like to be a researcher in a day to day capacity. This sparked some students to email us after the session asking for work experience, and general advice on progressing into university and research careers. To this end, we have begun to plan an outreach day where students are able to perform ligation of a chromoprotein gene fragment to a vector, transformation of the construct and subsequent screening activity - in order to experience the practical science that would otherwise be inaccessible in the secondary school setting. We have also set up online talks with some students who are interested in careers in scientific research, whereby advice is given as to what degree routes are available, what jobs are available and some of the up and coming areas of scientific research.

Women in Engineering Collaborative School Outreach

Our team collaborated with Women in Engineering (WiE) Society for an outreach session to Arbourthorne Community Primary School. Three members from our team (Chalisa, Marcus and Sanela) volunteered with two members from WiE (Emily and Lois) to introduce Year 5 and 6 students to genetics.

WiE is a student-led society aiming to inspire the younger generation into STEM by raising awareness of what engineering entails. Their society was established in 2012 and has grown to involve outreach to schools, site visits to plants, Wall of Women blog, and many more!

In July, Chalisa reached out to WiE volunteering outreach officers if they would be interested to do a collaborative session on genetics which is an important part of synthetic biology as well as bioengineering. The first meeting, joined by WiE President, Ioni, served as an introductory session to learn more about the outreach programmes WiE does weekly during the semester.

After agreeing on the collaboration, Lois contacted the Sheffield Students Union Volunteering Office to learn more about the possibility of having an outreach late September to early October. Arbourthorne Community Primary School was able to accommodate an outreach after school session on Tuesday 4th October, 2022. In the week prior to the session, Chalisa prepared the slides to make sure that they are engaging and suit the level of understanding Year 5 and

6 students would have. Lois helped with breaking down the instructions into simple steps for a tutorial worksheet where students can refer to. Aanchal from WiE helped with conducting risk assessments with the Students Union. Sanela sourced the plastic-coated wires and beads for the DNA model building activity and planned how to deliver the session in a fun and engaging manner so that the theory could be easily understood by the children.

We started the session with a mini warm-up quiz about inheritance and genetics before introducing the students to the concept of DNA. To our surprise, the students have an incredible understanding of DNA which makes it much easier for us to explain the DNA structure. As we did not want it to be too complicated, we decided to go to the extent of introducing the sugar phosphate backbone and 4 nitrogenous base pairs. The students were very engaged in the discussion about how DNA contributes to inheritance and why this explains the differences between different species.

As we move on to DNA model building, we anticipate that the students may not pay much attention and may lose their patience before finishing the model. However, the students were very concentrated and wanted to complete a DNA model that they could then bring back home. Unfortunately, we did not have enough time to finish off the DNA model which can then be attached to a key ring, but we offered each student the necessary materials and tutorial sheet that they can use to continue their models at home.

In conclusion, it was a successful outreach session with 33 Year 5 and 6 students. Their eagerness and willingness to learn more about the topic was far beyond our expectations. What went really well was how we managed to maintain the level of engagement from the start of the session to the end, as well as planning the content at the right level for them to understand. However, having more time would allow us to introduce the content slightly deeper and complete the reflection activity. Nevertheless, the students learnt a lot and we had met our target of inspiring them to explore STEM opportunities.

Coding with Biology Sessions

For our Coding with Biology sessions in collaboration with iGEM teams from UCL, Vienna and Cambridge, we hosted four workshops focused on educating biological science students on how to model dynamic biological systems effectively. For more information on this partnership, see our collaboration page!

To involve learners we published our raw data and the Pluto.jl notebook which allows learners to code in an interactive Julia environment, in order to repeat our growth curve analyses or take them

even further! We also have provided the video for their reference and viewing pleasure, and a helpful PDF that highlights the two-language problem and the advantages (and disadvantages) of Julia. If you are interested in playing with the interactive Julia notebook yourself you can find that and our raw growth curve data on our GitLab.

Because it's important that our educational material has a life beyond that of this year's team, we've recorded all of the original Data Analysis in Julia session and published it here for anyone to rewatch! Perfect if you'd like some more clarification or detail regarding the content of the notebook![2]

[2] `https://video.igem.org/w/xmWfx73fnufLnioC7bJm8X`

'Introducing AlphaFold' Session

Following the introduction of AlphaFold at the Critical Assessment of Techniques for Protein Structure Prediction (CASP), in December 2018, it has widened synthetic biologist's knowledge of protein structures and poised researchers for a future of directed evolution and de novo protein designs. Despite it's high popularity amongst keen protein researchers, learning the basics of the software for University students and iGEM teams is fairly inaccessible. Hence, we decided to get in contact with academics within the University of Sheffield who work with the software to help introduce it and how it can be used in research. So we planned an 'Introduction to AlphaFold Session' for iGEMers and students to join and get an insight into the wonders of protein 3D structure!

P.h.D. student, Adam Bowie, of the Photosynthesis Research Group at the university has since given a talk illustrating how AlphaFold has aided his work in designing a new photosystem that has a broad photosynthetic spectrum of light absorption, as well as how to input and interpret AlphaFold data.

Following this talk from Adam Bowie, our very own de novo protein genius, Isaac White, discussed research that he had recently discovered when writing his impressive literature review "Saving Lives With Molecular Origami". In this talk Isaac discusses how structural prediction software is being repurposed to aid the de novo protein design of proteins in relation to medicine, and gave a wonderful insight into the future of computational protein design.

Finishing up, Brooks Rady, also of the Sheffield iGEM team, hosted a AlphaFold workshop, showing first hand how iGEM teams can use ColabFold, a more accessible alternative to AlphaFold, to investigate protein structures, and even gave am illuminating demonstration on how we have used this tool to successfully model how we can successfully fuse two proteins together while keeping their three-dimensional structures intact.

Each session was met with inquisitive questions from other students and Adam himself, who expressed particular interest in ColabFold as a more accessible and fast tool for him to use in his research. We recorded the session and sent it to all iGEMers and students who had previously expressed interest, as well as including it on our Wiki here! If you have any questions or queries regarding our talks, don't hesitate to contact us.[3]

[3] https://video.igem.org/w/rmWuPLcQZ4pYY4S1vBFts7

Maker's Fair Outreach

On the 26th of September, the University of Sheffield held a Maker's Faire that showcased some of the many student-led initiatives during an event open to both current students and the wider public. Sheffield iGEM was one of the featured stalls in Firth Hall, and being such an interdisciplinary initiative, we generated a great deal of interest for students studying degrees ranging from life sciences to traditional engineering.

We showcased our working bioreactor, demonstrating how we have applied engineering design principles in a synbio context. Students were allowed to alter the code to see directly how these changes modulated the bioreactor. Some students even provided their own insights and ideas for future build iterations. Alongside this, we gave talks to students about the principles of synthetic biology and genetic circuit design. It was interesting to see how students from, for example, a mechanical engineering background, could cognise the capabilities of genetic circuitry within their own educational framework. Many students were struck by how much one would have to think outside the box when designing something so interdisciplinary.

By the end of the fair, we had generated a great deal of interest amongst students who would like to participate in next year's iteration of iGEM, as well as introducing students to the world of synthetic biology. Some students were not aware that synthetic biology had advanced enough as a field to have widespread, fundamental impacts in a variety of industries from pharmaceuticals to material engineering. It was a rewarding, enriching experience for everyone involved.